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Contamination of Vegetation by Lead and Other Elements in the Vicinity of the Canada Metal Company
Eastern Avenue, Toronto - 1986, 1987

Introduction

The Phytotoxicology Section has surveyed lead contamination of vegetation and/or soil near the Canada Metal Company (CMC), Toronto, annually since 1972. Results of tree foliage sampling conducted in 1985 and earlier years have revealed elevated levels of lead, arsenic, cadmium and antimony relative to the Gerrard Street Control Area in Toronto.

Methods

In September of 1986 and 1987, samples of tree foliage were collected from 24 stations in the vicinity of the Canada Metal Company (Figure 1), from the sides of trees facing the company. Control samples of *Ailanthus* and Norway Maple foliage were also collected in September of each year from 10 stations (total 20 samples) in the Gerrard Street Control Area in downtown Toronto (Figure 2).

Soil sampling at each station was not conducted in 1986 or 1987. A separate and extensive residential soil sampling program, for the purposes of soil replacement, was carried out in the area in 1987 by a consultant.

Distance and direction of sampling stations were calculated with reference to a point located approximately equidistant from the main stack, the lead oxide building and the south cupola. This point is indicated by a star in Figure 1.

Vegetation samples were processed in the Phytotoxicology laboratory, and were analyzed for lead (Pb), arsenic (As), cadmium (Cd) and antimony (Sb), all of which are potential emissions from CMC, by the MOE Laboratory Services Branch.

In this report, results are compared with those of earlier years and with Phytotoxicology Section "upper limits of normal" (ULN) guidelines (non-legally enforceable) which were developed statistically (mean plus three standard deviations) from data for urban samples not considered to be influenced by industrial point sources. Comparisons also are made with other air quality monitoring results (dustfall and suspended particulate).

Results

Lead

Lead concentrations in unwashed tree foliage samples collected in September of 1986 and 1987 are shown in Table 1, and are compared with prior years' results. Average lead levels and percent of stations which exceeded the foliar guideline are illustrated in Figure 3. Average levels in 1986 were the lowest of any year since Phytotoxicology sampling began. However, average levels in 1987 were substantially higher than 1986 and similar to those found in 1984. The percentage of stations having foliar lead concentrations exceeding the ULN guideline (60 µg/g) in 1987 was the highest since 1982. In comparison to the control area mean results, the mean lead concentrations in samples collected in the vicinity of CMC were higher by factors of 4 and 6 in 1986 and 1987, respectively (Table 4).

Elevated lead concentrations in 1987 were measured at distances up to 240 m N, 200 m NNE, 90 m E, 200 m ESE and 330 m SW of the source reference point. On the basis of the foregoing comparisons it is apparent that there has been no detectable improvement in the degree or extent of foliar lead contamination in the vicinity of the CMC plant over the period 1980 to 1987.

Sources of Lead in Foliage

The major source of lead in tree foliage near CMC is believed to be direct deposition of air-borne lead emitted from the smelter operations. The main evidence for this is the pattern of contamination. The second most important source may be re-entrainment of contaminated soil and dust. Re-entrainment can be estimated by using concentration ratios of tracer elements to contaminants in surface soil and foliage. In 1983, it was estimated by this technique that re-entrainment could account for an average of 11% of lead in tree foliage collected at the CMC sampling stations.

A significant proportion of foliar lead contamination can result from general urban sources. In 1986 and 1987, the average lead concentration in control area tree foliage (10 µg/g;Table 1) expressed as a percentage of the CMC-Mean averaged 18%; whereas in previous years this percent has averaged over 30%. Direct root uptake of lead from contaminated soil is an additional source of foliar lead near CMC; however, in view of the low degree of availability of soil lead for uptake by plants, as evidenced by numerous reports in the literature, this pathway is regarded as minor.

Effect of Rainfall

Amount and timing of rainfall might be expected to influence contaminant concentration results obtained with unwashed tree foliage samples. In order to ensure that inter-year comparisons of unwashed foliar lead results are valid, rainfall statistics were examined. The figures in Table 2 show variations in rainfall, as measured at Pearson Airport, for the period 1977 to 1987. Total rainfall for the 2-week and 5-day periods preceding the CMC sample collection dates are shown. The correlation coefficient between the 2-week rainfall and average foliar lead concentration was + 0.27 while that between 5-day rainfall and foliar lead was +0.79. These positive correlations are surprising and, because rainfall has been shown in other studies to slightly decrease foliar concentrations of air-borne contaminants, they must be regarded as coincidental and/or subject to other climatic or source related variables.

Results from a separate experiment conducted near CMC in September 1986, while not conclusive, indicate that substantial variations (to ± 100% of mean values) in the 2-week and 5-day periods prior to sample collection do indeed exert a fairly small washing effect (up to approximately 15%) on measured tree foliage lead concentrations. The 5-day period rainfall:concentration relationship was slightly more significant than the 2-week period relationship. It was determined from the results of this experiment that foliar lead concentrations were reduced by approximately 2.2% for every 10 mm of rain in the 5-day period preceding sample collection.

The main conclusion to be reached is that the increase in foliar lead concentrations near CMC in 1987 compared to the two prior years cannot be ascribed to rainfall variation.

Comparison With Air Quality Monitoring Results

The Ministry of the Environment maintains a network of "hi-vol" (to measure total suspended particulate or TSP) and dustfall samplers in the vicinity of the Canada Metal Company (Figure 4). Dustfall and TSP lead results are compared with foliar lead levels near CMC in Figure 5. The selection of the four-month June to September period for comparison of air quality results was made on the basis of data availability and degree of agreement with tree foliage results. There is reasonable agreement in year-to-year variation in lead results as obtained by these three techniques. The correlation between foliar lead and dustfall lead is significant ($p \leq 0.05$) while that between foliar lead and suspended particulate lead is highly significant ($p \leq 0.01$).

It is apparent from Figure 5 that growing season environmental lead contamination in the vicinity of CMC decreased between 1977 and 1981 but there has been no trend towards improvement since then. Tree foliage and suspended particulate lead levels increased in 1987 over the previous two years whereas dustfall lead did not. Both dustfall and suspended particulate lead levels near CMC have been and continue to be well in excess of "urban background" levels of approximately 10 $mg/m^2/30$ d and 0.2 to 0.4 $\mu g/m^3$, respectively.

Comparison of Ambient Airborne Lead as Measured by Moss Bag and Hi-vol Sampler

An alternate method to measure air-borne particulate lead, used by the Phytotoxicology Section, is the moss bag. Small packets of Sphagnum moss are enclosed in a plastic mesh and mounted at ≈ 3m height on poles (e.g. utility poles) near the source to be monitored. The moss bags, which intercept airborne contaminants, are replaced monthly and subsequently undergo chemical analysis.

Hi-vol sampler Station 31058 is located 120 m NE of the CMC reference point; CMC moss bag Station 3 is located 240 m NE of CMC (Figure 4). Although the two methods of measuring monthly levels of atmospheric lead contamination express the results in different units, a comparison could be carried out for the period July 1985 to December 1987 (Figure 6). The correlation coefficient for the two methods is 0.56 (significant at $p < 0.01$). This is a moderately good agreement considering:

a) the inherent differences in methods
b) the stations (one each only) were in different locations, and
c) for much of the comparison period the "monthly" periods were out of phase; i.e., the moss bag month was actually three weeks of one (hi-vol) month and one week into the next.

A general examination of Figure 6 corroborates earlier conclusions that there is no clear trend of changing airborne lead levels near CMC for the period January 1985 through December 1987, although, as previously discussed, growing season suspended particulate lead levels were higher in 1987 than in 1986. The moss bag levels were elevated in comparison with the Phytotoxicology Section "upper limit of normal" lead concentration in urban moss bags (200 µg/g) for 6 of the 30 monthly monitoring periods. The hi-vol results routinely exceeded urban background concentrations (0.2-0.4 µg/m^3).

Arsenic, Cadmium and Antimony Results

Arsenic, cadmium, and antimony results for tree foliage collected near CMC for the years 1983 to 1987 are summarized in Table 3.

Results from 1986 and 1987 show that concentrations of antimony, cadmium and to a lesser extent arsenic exceeded those found in the Toronto control area, with the significance of the differences being especially large for antimony (Table 4). The percentage of stations with concentrations in excess of ULN guidelines also was highest for antimony (33 and 75% in 1986 and 1987, respectively. In spite of a slight elevation, arsenic concentrations were considered to be within normal levels for an urban area. Although average cadmium levels in CMC foliage exceeded control area levels, elevated cadmium levels were associated with known cadmium accumulator species in the CMC area.

In general, distributions of these three contaminants in tree foliage were similar to those for lead, with levels decreasing with increasing distance from CMC. Antimony levels in particular are reflective of lead levels, with higher foliar antimony concentrations being measured in 1987 and 1984 than in 1986, 1985 or 1983.

Summary

Concentrations of lead, antimony, and to a lesser degree cadmium and arsenic in unwashed tree foliage collected in the vicinity of the Canada Metal Company in 1986 and 1987 were significantly elevated with respect to the Gerrard Street Control Area in downtown Toronto. Many of the lead and antimony results within the CMC area also were well above the corresponding Upper Limits of Normal guidelines established by the MOE. Concentrations of arsenic and cadmium were considered to be within "upper limits of normal" for an urban area.

A comparison of annual contaminant concentrations in unwashed tree foliage near CMC reveals that there has been no overall trend towards decreasing lead levels since 1980. In fact, the 1987 levels increased slightly from the previous two years.

The lack of any apparent significant improvement in the status of lead contamination from CMC during this period also is evidenced from the results of dustfall and total suspended particulate monitoring, which show reasonably good agreement with the vegetation and moss bag results.

In a review of the results presented in this report, experts from the MOE Hazardous Contaminants Co-ordination Branch expressed concern regarding the human health significance of exposure to the elevated lead levels.

TABLE 1: Lead concentrations (µg/g, dry wt.) in unwashed foliage samples collected in September of 1977 and 1979 through 1987 in the vicinity of the Canada Metal Co., Toronto

Station	Distance (m) and Direction from Reference Point	Species Sampled	Lead Concentration									
			1977	1979	1980	1981	1982	1983	1984	1985	1986	1987
NNW Direction												
65	150 NNW	Nowway maple	166	98	56	55	61	39	47	56	29	93
17	300 NNW	Norway maple	59	23	27	37	16	29	21	-	18	22
18	365 NNW	Norway maple	41	56	29	51	28	25	26	17	13	15
68	410 NNW	Norway maple	-	-	-	-	-	-	-	(17)	(9)	(11)
20	490 NNW	Silver maple	21	-	27	14	20	23	48	15	13	21
NNE Direction												
2	200 NNE	Norway maple	292	740	98	108	100	86	160	125	142	205
1	190 N	Elm	124	-	158	91	184	92	155	136	120	215
9	240 N	Elm	152	-	124	83	122	113	255	47	85	120
11	360 N	Willow	52	-	46	33	50	39	70	28	35	33
67	400 N	Silver maple	-	-	-	-	-	-	-	(18)	(18)	(23)
12	485 N	Elm	49	-	70	16	81	55	78	62	41	38
13	575 N	Norway maple	100	-	17	28	16	36	22	22	42	16
15	730 NNE	Norway maple	34	-	12	19	11	11	10	11	35	6
NE Direction												
5	470 E	Linden	27	-	40	46	34	47	38	38	30	45
ESE Direction												
58	90 E	Ailanthus	560	-	128	142	119	94	26	96	59	125
59	200 ESE	Norway maple	142	193	98	54	25	38	38	90	37	92
66	495 SE	Poplar	-	-	42	24	17	42	60	42	33	51
SW Direction												
50	150 SW	Willow	214	117	110	113	119	77	175	51	72	220
44	330 SW	Willow	44	-	46	54	63	31	36	21	21	86
WNW Direction												
33	220 NW	Norway maple	58	82	40	55	46	41	50	44	35	46
34	285 WNW	Norway maple	61	86	55	65	32	55	38	42	32	39
35	345 W	Silver maple	81	133	46	75	67	61	78	40	51	53
27	425 NW	Norway maple	69	56	49	27	42	32	31	39	21	31
28	500 WNW	Norway maple	31	39	17	30	19	35	27	25	17	14
CMC - Mean: (bracketed values excluded)			113	-	61	55	58	50	68	50	43	68
- Minimum: (" " ")			21	23	12	14	11	11	10	11	13	6
- Maximum: (" " ")			560	740	158	142	184	113	255	136	142	220
Control Area - Mean			40	44	18	19	15	18	17	22	9	10
% of CMC stations (excl. bracketed values) exceeding current "upper normal" level* (underlined)			52	-	32	32	41	27	32	24	18	36

*Note: - Phytotoxicology Section "upper limit of normal" lead concentration in unwashed urban tree foliage is 60 µg/g.

Table 2
Rainfall Statistics (Pearson Airport)

Year	Vegetation Collection D es (Canada Meta	Rainfall in 2 week period prior to sample collection (mm)	Rainfall in 5 day period prior to sample collection (mm)	Average lead concentration (µg/g, dry wt.) in unwashed CMC tree foliage samples
1977	Sept. 27	99.8	67.7	113
1979	Sept. 18	42.7	36.6	-
1980	Sept. 23	35.9	19.3	61
1981	Sept. 24	20.4	15.8	55
1982	Sept. 27	123.9	37.2	58
1983	Sept. 13,1	1.2	0	50
1984	Sept. 11	64.5	27.1	68
1985	Sept. 16	36.6	0	50
1986	Sept. 16,1	117.0	31.3	43
1987	Sept. 15,1	49.2	43.0	68

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Table 3

Summary of arsenic, cadmium and antimony levels (μg/g, dry weight) in unwashed tree foliage near the Canada Metal Company - 1983, 1984, 1985

Statistical Parameter	Arsenic	Cadmium	Antimony
1983 CMC - Mean:	0.41	0.50	0.83
- Minimum:	0.10	<0.1	0.24
- Maximum:	0.77	3.8	2.1
Control Area Mean:	0.12	<0.1	0.11
% of CMC stations with "above normal concentrations:	0	4.5*	77
1984 CMC - Mean:	0.52	0.62	1.16
- Minimum:	0.10	<0.1	0.14
- Maximum:	1.5	4.4	4.8
Control Area Mean:	0.19	<0.1	0.07
% of CMC stations with "above normal" concentrations:	0	4.5*	68
1985 CMC - Mean:	0.37	0.55	0.90
- Minimum:	0.12	<0.1	0.16
- Maximum:	0.91	4.6	3.6
Control Area Mean:	0.21	<0.1	0.21
% of CMC stations with "above normal" concentrations:	0	4.3*	57
1986 CMC - Mean:	0.3	0.45	0.52
- Minimum:	0.05	<0.1	0.07
- Maximum:	0.70	4.0	2.3
Control Area Mean:	0.14	<0.1	0.08
% of CMC stations with "above" normal concentrations:	0	4*	33
1987 CMC - Mean:	0.3	0.48	1.20
- Minimum:	<0.3	<0.1	0.23
- Maximum:	0.90	4.0	3.2
Control Area Mean:	<0.3	∿0.1	∿0.3
% of CMC stations with "above normal" concentrations:	0	4*	75
Phytotoxicology Section "upper limits of normal" concentrations in unwashed urban tree foliage	2	3	0.5

* "Above-normal" cadmium concentrations were present in known cadmium accumulator species only.

Table 4

Comparison of CMC-Mean Data with Control Area-Mean: 1986, 1987

Year	Factor by which CMC Sampling Area Mean Exceeds the Corresponding Control Area Mean - Unwashed Tree Foliage			
	Pb	As	Cd	Sb
1986	4	1	>3	5
1987	6	<1	4	3

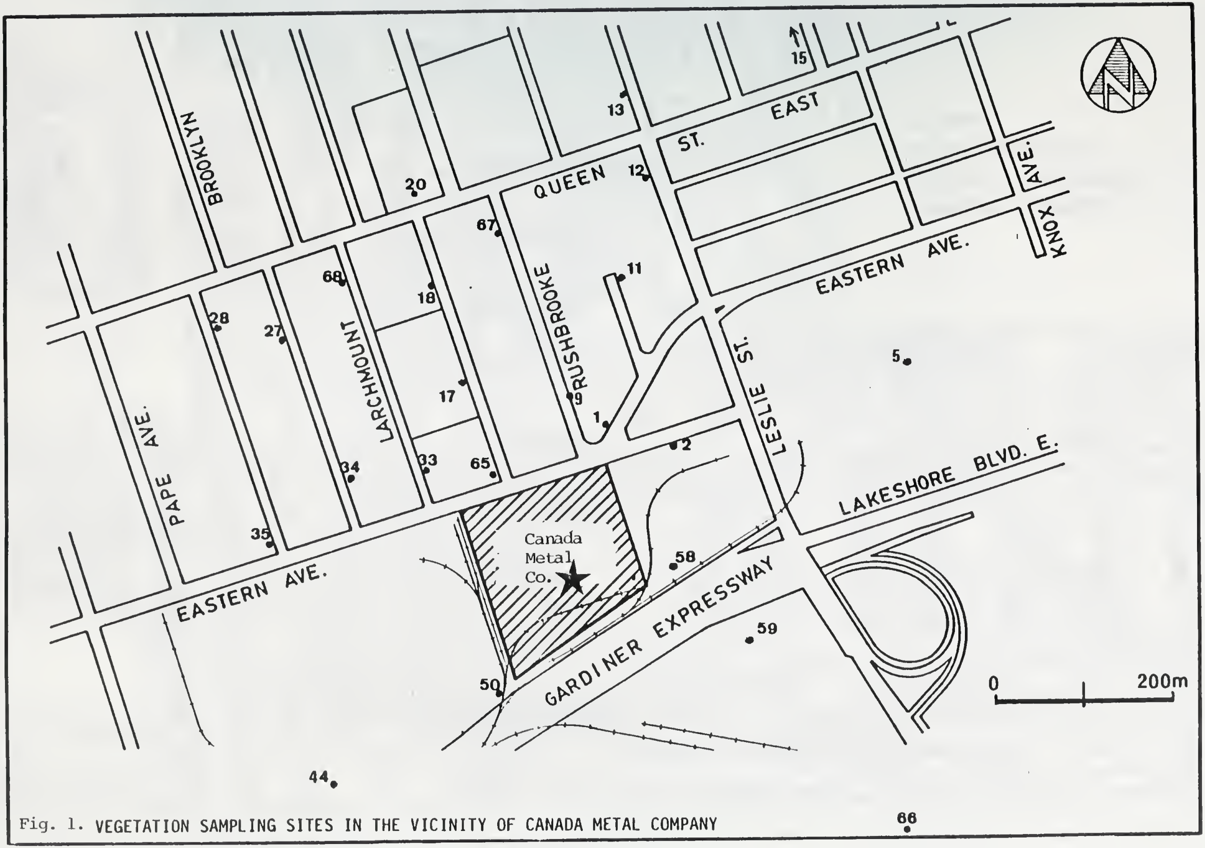


Fig. 1. VEGETATION SAMPLING SITES IN THE VICINITY OF CANADA METAL COMPANY

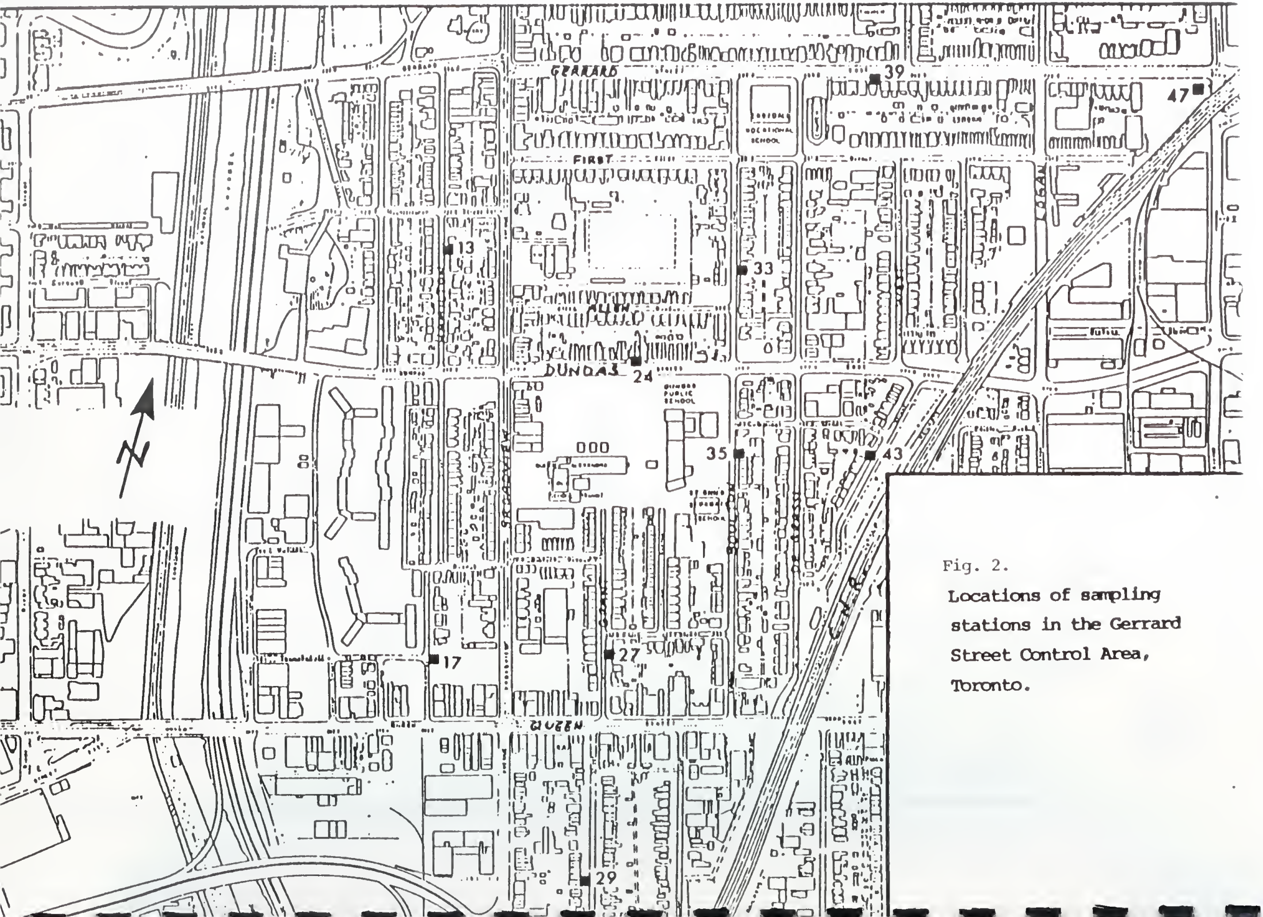
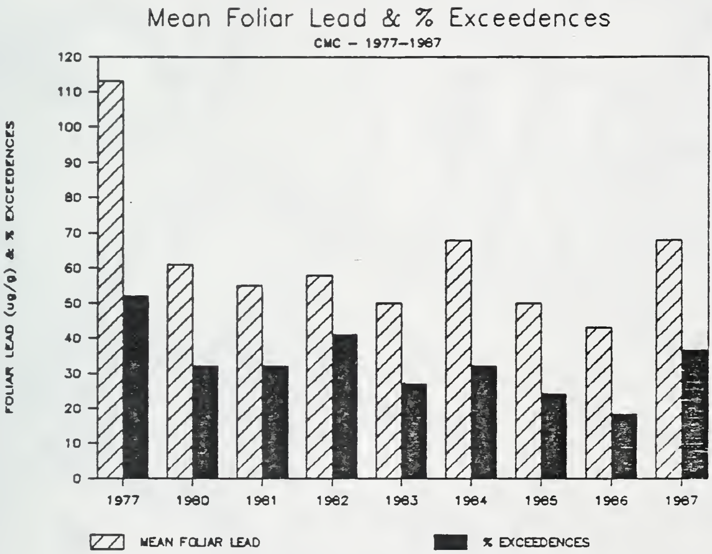


Fig. 2.

Locations of sampling stations in the Gerrard Street Control Area, Toronto.

Fig. 3.


Mean Foliar Lead & % Exceedences
CMC – 1977–1987
FOLIAR LEAD (ug/g) & % EXCEEDENCES
120
110
100
90
80
70
60
50
40
30
20
10
0
1977
1980
1981
1982
1983
1984
1985
1986
1987
MEAN FOLIAR LEAD
% EXCEEDENCES

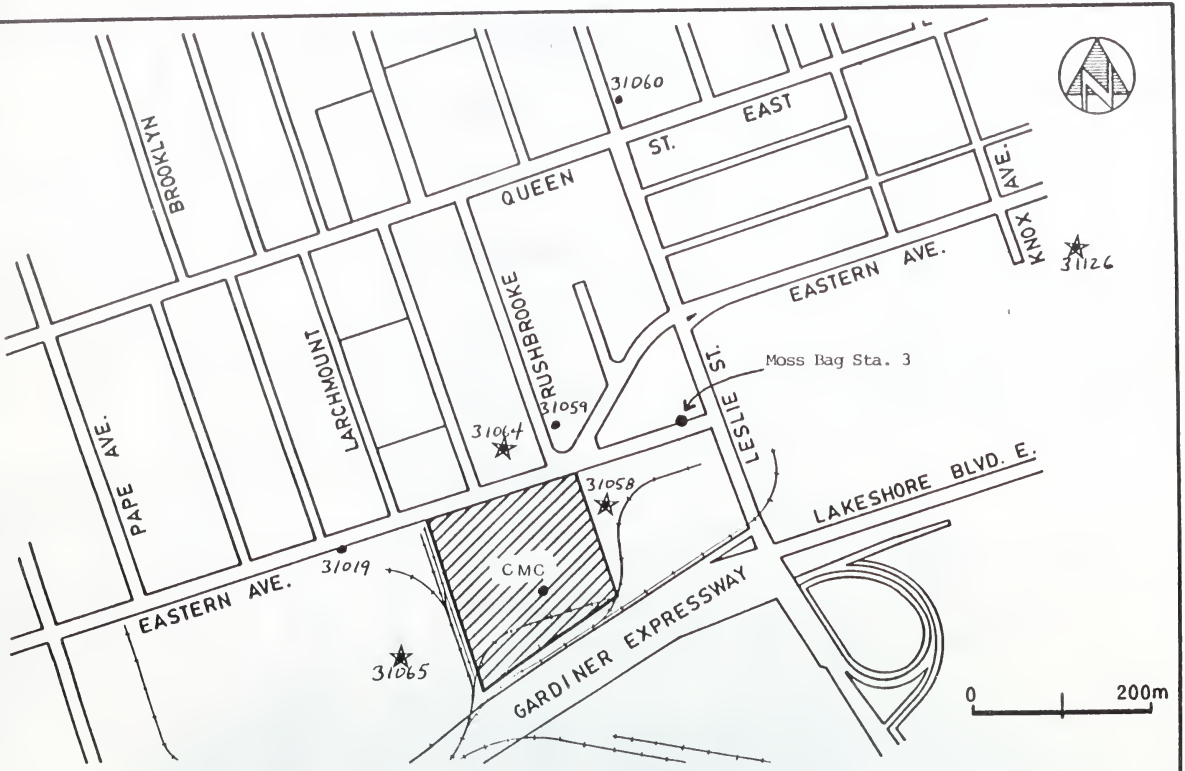
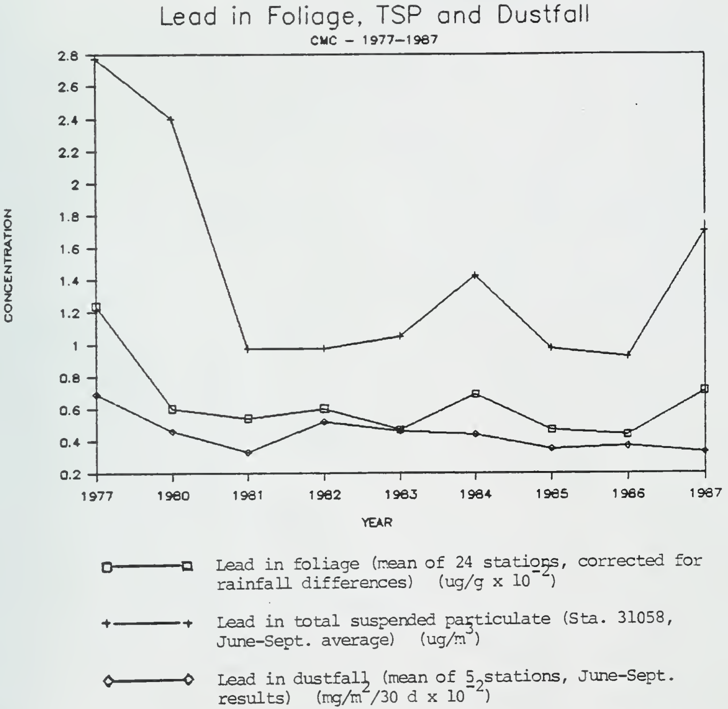


Fig. 4. Dustfall collectors in the vicinity of Canada Metal Co. Star indicates hi-vol sampler also present.

Fig. 5.


Lead in Foliage, TSP and Dustfall
CMC – 1977–1987
CONCENTRATION
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
1977
1980
1981
1982
1983
1984
1985
1986
1987
YEAR
Lead in foliage (mean of 24 stations, corrected for rainfall differences) (ug/g x 10^{-2})
Lead in total suspended particulate (Sta. 31058, June-Sept. average) (ug/m^3)
Lead in dustfall (mean of 5 stations, June-Sept. results) (mg/m^2/30 d x 10^{-2})

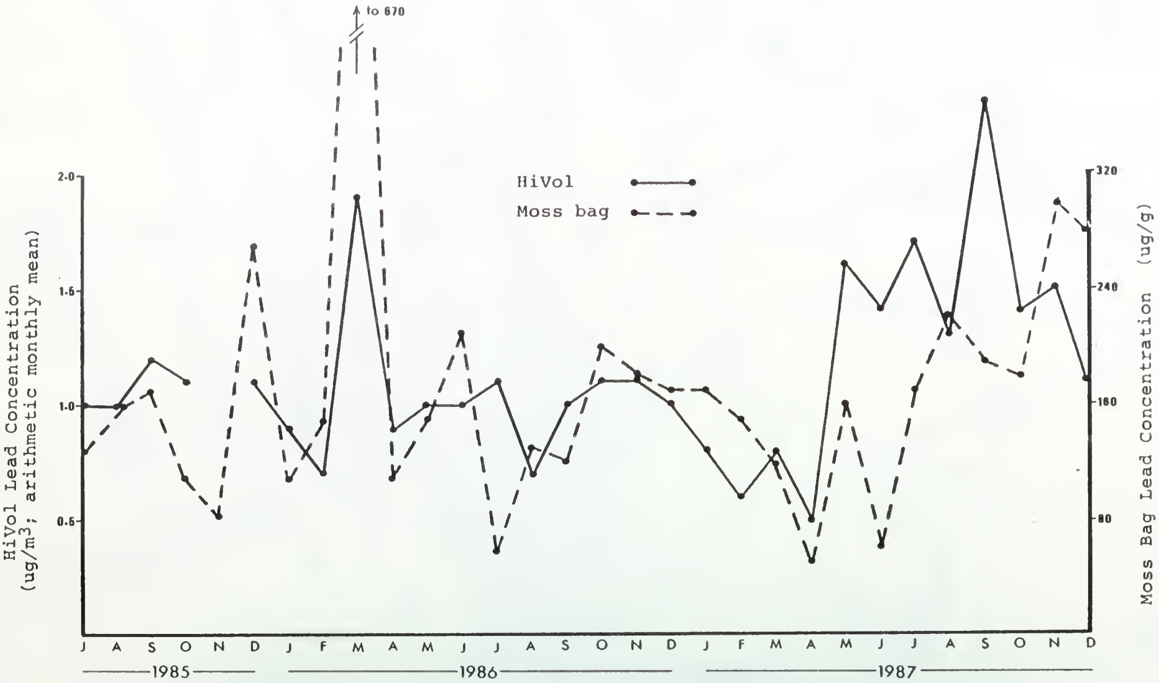


Fig. 6. Monthly values of airborne lead contamination near Canada Metal Company as measured by high volume sampler (31058) and moss bag (CMC #3), July 1985 - December 1987.